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Title: MODEL-BASED ESTIMATE OF GLOBAL COPPER RESOURCES
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Abstract: The age of ore deposits at the surface reflects primarily the depth at which they formed, with deposits that formed at shallow levels in the crust being exhumed more quickly (in geological terms) than deposits that formed at deep levels. Age-frequency distributions for epithermal and porphyry copper deposits, which form at successively deeper crustal levels in convergent margins show an abrupt increase in the number of deposits to a maximum (modal) number, and then a gradual decrease in the number of increasingly older deposits. Proof that these distributions are controlled by exhumation is provided by the fact that they can be used to calculate exhumation rates similar to those obtained for convergent margin terranes by other methods.

We have developed a computational model that reproduces the observed age-frequency distributions for ore deposits by simulating the tectonic movement of deposits within Earth's crust and their appearance at the surface. Computationally, the model forms a series of deposits of a specific type and allows them to move upward or downward, or to remain at the same level (stasis) with the passage time such that individual deposits in the series follow many different paths through the crust. The model allows the first quantitative assessment of global resources because it provides information on the number of deposits at all depths in the crust, including depths that are far below those constrained by reasonable extrapolations of surface and near-surface geologic information.

Model simulation based on their age-frequency distribution indicates that Earth has formed approximately 100,000 porphyry copper deposits through Phanerozoic time, that about one-third of them (containing about 10^{11} tonnes of copper) remain in the crust, and that less than 2% of these have been discovered. Including other types of copper deposits on the basis of their contribution to currently known reserves, results in an estimate of $1.8*10^{11}$ tonnes for total global copper resources at all levels in Earth's crust. Comparing to the average copper abundance for crustal rocks indicates that about 0.14% of the copper in Earth's crust has been concentrated into ore deposits through Phanerozoic time and about two-thirds of this has been recycled by weathering and erosion.

The only number to which our model result can be compared, is $9.9*10^8$ tonnes, which the U.S. Geological Survey estimated recently for the copper endowment of the United States to a depth of 1 km. Our model yields a very similar value of 5.8*10^8 tonnes for this crustal slice. Assuming 3.3 km as the likely limit of mining in the foreseeable future, our model indicates that about $7.6*10^{10}$ tonnes of copper is present in deposits to this depth, making this a likely estimate of future global copper resources.